Problem 6: Airline schedule assignment and construction

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Problem Statement

Given

- Flight schedule (individual flight legs for a period, typically a season);
- Airline's fleet of aircraft (resources).

Constraints

- Flights must connect geographically (departure airport must be same as previous arrival).
- Flights *should* have a gap ("recommended ground time") between one another, which depends on the airport.
- Flights *must* have a gap between one another (also airport dependent) which is the "minimum ground time".
- Flight legs of the same flight must have an inter-leg gap of at least the the minimum passenger connecting time if there is an aircraft change (a flight is identified by a single number for all of its component legs, and a "flight date", being the departure date of the first leg).
- There are carry-in and carry-out flights at each end of the period which must also connect with the flights inside the period (including both geographic and ground time constraints).

Variant 1

- Each flight leg has a designated aircraft type.
- Each flight leg has a fixed departure and arrival time.

Objective function

- In this scenario, we can't eliminate or rebuild the schedule – it is a given. The problem will arise that we might be unable to fit all of the flights onto the fleet.

- Usual solution: Add "pseudo" aircraft – there is cost or penalty associated with putting a flight on a pseudo aircraft (What cost? This depends on what the business intends the meaning of assignment to a pseudo aircraft to be: does it imply cancellation of the flight; or leasing in an aircraft; or re-accommodating passengers on another airline's at the last minute).
- Violating a recommended ground time also incurs a penalty; so what is the balance between squeezing flights in using short ground times, versus placing them on pseudo aircraft? There is also usually a limit to how many violations are allowed in a rolling time window.
- It may in fact be impossible to assign the flights without breaking geographic continuity at the carry-in and/or carry-out points – i.e. technically the problem is infeasible, but airlines don't want to view it as infeasible. They want a "best possible" solution – which reduces the geographic connectivity constraint to a cost rather than a constraint – i.e. a geographic continuity has a penalty associated with with.
- Objective: MIN SUM (penalties).

Problem

Can this problem be posed and solved and a MILP problem?

Otherwise, how shall we solve it? Heuristic algorithms (e.g. simulated annealing, other non-linear)?

Variant 2

- Each flight leg has a *preferred* aircraft type (marketing dept. has attempted to fit forecast demand to seating capacity, but this is not mandatory)
- Each flight leg has a fixed departure and arrival time

Objective function

- A new cost (or "penalty") is introduced, which is incurred when assigning a flight to the wrong aircraft type (which might imply a loss of passenger carrying capacity) – how does that cost balance with the cost of assigning to a pseudo-aircraft (which implies flight cancellation or leasing in an aircraft)?
- MIN SUM (penalties)

Problem

- See that this makes for a much bigger problem because all of the aircraft types among which flights may move must be solved together (the problem cannot be partitioned by type).

Variant 3

- Flights legs can move around in time (how much movement is permitted?)
- This leads to the next possibility: addition / cancellation of flights

Problem

- How do we even pose the problem?

- Are the times real or integer – should we quantize the day (at what resolution? some airlines schedule at 5 minute intervals; others at 1 minute: there are 1440 minutes in a day, so that adds a vast additional number of degrees of freedom to every flight). It is better to to quantize the day into say 1440 intervals adding 1440 DF to each flight, or to treat the time as a real, which means it must move to a “corner” of the hypercube? But it may be impossible pose the problem with times as reals.
- What would a good objective function be? Still minimizing penalties? We must surely introduce some measure of how suitable or unsuitable the timings are -e.g. a passenger network flow model to see when our passenger demand falls during each day, so we need to add revenue component to the model (or a surrogate for revenue, something like passenger-hours filled – not just passenger-hours offered).